PUBLIC HEALTH REPORTS

VOL. 33 MARCH 22, 1918 No. 12

HEALTH HAZARDS FROM THE USE OF THE AIR HAMMER IN CUTTING INDIANA LIMESTONE.

By J. P. LEAKE, Passed Assistant Surgeon, United States Public Health Service.

1. The Industry.

Indiana limestone from the vicinity of Bedford, Ind., is at present the most important building stone in America. Beside its architectural qualities, its value is due largely to the ease with which it can be quarried and worked in large quantities. It is of fine texture, of the class called oölitic because of the small egg-like fossils of which it is composed, of even consistency, and comparatively soft to the tool.

The center of the industry is Bedford, a city of 10,000 population, the county seat of Lawrence County; Bloomington, a city of about the same size, the county seat of Monroe County, adjoining Lawrence County on the north, is next in importance as a stone center; Ellettsville and Stinesville, north of Bloomington, are smaller centers. Bedford has railroad shops and other small factories, but it is essentially a town of one industry—stone—while Bloomington is the seat of the State university and enjoys more varied activities.

There are 39 stone companies in the district. Though some of these engage in both branches of the work, a sharp line is drawn between the production of rough or machine-tooled stone and the production of dressed or cut stone. It is only the latter with which this investigation is concerned.

The greater part of the quarrying for Bedford is near Oolitic, a town of about a thousand inhabitants, 4 miles northwest of Bedford. For all but the preliminary squaring off of the blocks (the process called scabbling) the stone is brought to the mills in Bedford. These mills are very large buildings, some operating as many as seven 10 or 15 ton electric cranes and containing tracks for the loading and unloading of freight cars. On account of their size and height, and the wide doors, they are difficult to heat; moreover, they contain no intrinsic source of heat, such as the furnaces of a steel mill.

In general, the blocks of stone from the quarries are first sawed into large slabs by reciprocating gang saws. These are strips of steel without teeth, the abrasion being furnished by a mixture of sand and

water, which is fed from above. Next, the slabs may be sawed by large circular saws with black Brazilian diamond teeth (Fig. 1). This is also a wet process; the spray is largely gathered by the hoods over the circular saws. If the stone is not to be cut by hand, machine dressing follows next; steel cutting instruments are used on the planers, circular planers, and lathes without further moistening of the stone. In the planing machine the block of stone reciprocates on a bed beneath the tool, which takes off one layer after another in a coarse powder, producing fluting and other straight line figures which were formerly cut by hand.

The stonecutting (hand cutting) is usually done at one side of the main craneways (Fig. 2), and, as observed at the time of this investigation, the air hammer was almost entirely employed for this work, except in the case of the apprentices, who are required to use the mallet in the old-fashioned way. This work, whether plain cutting or carving more intricate figures, such as statuary and Corinthian capitals (Fig. 3), is done in two parts, called "roughing out" and "cleaning up." In "roughing out" the block of stone is roughly shaped to the form which it is finally to assume, and the steel hand hammer or wooden mallet is occasionally used to deliver the impacts; this part of the work is less exacting and less time-consuming than the finishing or "cleaning up" for which the pneumatic hammers appear to be used exclusively by the journeyman cutter. But the division between "roughing out" and "cleaning up," as that between plain stonecutting and carving, is not a sharp one.

There are normally 200 or 300 stonecutters in Bedford, 50 to 75 in Bloomington, and smaller numbers in Ellettsville and Stinesville. On account of inactivity in stone construction, much smaller numbers were found employed, and the employment varied from day to day. In general, however, the employment has been fairly steady and permanent; the stonecutters are a superior class of workmen, many owning excellent homes. Their hours of labor are strictly limited to 8 per day and 4 on Saturday, 44 hours a week. The wages at the time of the investigation were 67½ cents an hour. The carvers are not hired directly by the mills, but this work is let to subcontractors, who employ other carvers, by the hour, to help them.

In the stone industry, pneumatic tools were probably first used on granites and the harder stones. The first air hammer was introduced in Bedford about 22 years ago, and use of these hammers became universal in this district about 7 years ago. The air compression is maintained by steam air pumps and tanks at about 85 pounds per square inch, and is piped to the place of carving. Flexible pressure hose connects the air pipes with the hammer; the air is turned on for each hammer by a thumb cock in the rubber hose about 3 feet from the hammer. Various makes and sizes of pneu-

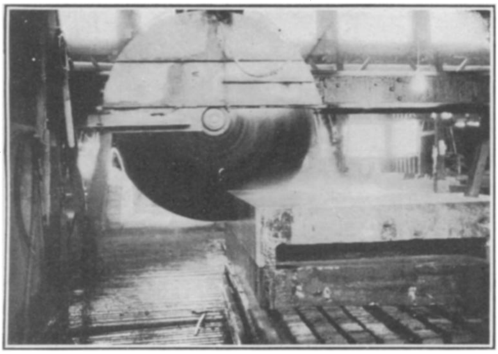

Fig. 1.—Circular diamond saw. The teeth of the saw consist of black Brazilian diamond, and the wet saw cuts through thick blocks at the rate of several inches per minute. The stone as it reaches the cutter is not visibly moist, but has not completely dried out from the sawing.

Fig. 2.—Cutting stone with the air hammer. The cutter in the right foreground is left-handed.

Fig. 3.—Carving with the air hammer.

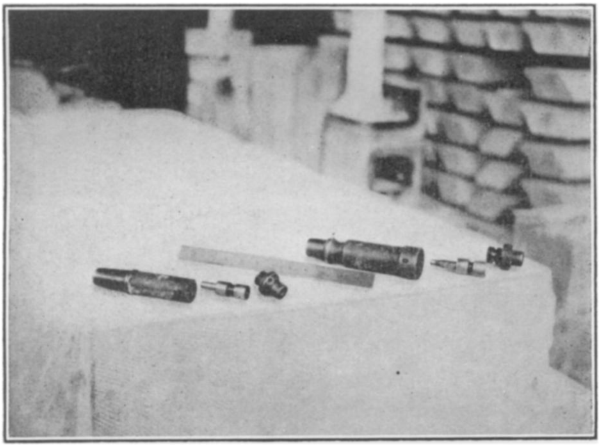

Fig. 4.—The three parts of the air hammer. The cylinder, piston, and head of the three-quarter inch hammer are shown to the left of the foot rule, and those of the 1-inch hammer to the right of the foot rule. The hose is coupled to the head, the tool being inserted in the other end of the cylinder. In the three-quarter inch hammer the exhaust is in the head; in the 1-inch it is in the cylinder near the head.

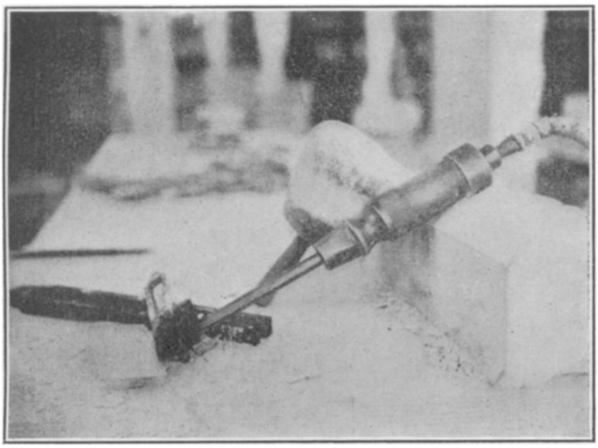

Fig. 5.—Platen for measuring vibration frequency attached to the tool in an air hammer. One tuning fork is in position for recording. This is more clearly shown in figure 6.

matic hammers were seen. The three parts of each of the two sizes of a hammer frequently used are shown in figure 4. The reciprocating strokes are produced by the piston alternately opening and closing inlet and exhaust openings at various points on the interior of the cylinder (piston valve) and thus responding to the force of the air pressure.

The tool is not attached to the hammer, but must be held in the point of the hammer by the hand. The tools are about 10 inches long, including a butt of about 1½ inches which fits into the hammer. The diameter is variable, frequently about half an inch, giving a weight of about 9 ounces.

The dimensions of the two hammers are approximately as follows:

	Three-quarter inch.	1 inch.
Total length	6.7 inches	8 inches.
Total weight (without tool)	1¾ pounds	3¾ pounds.
Outside diameter	1.2 inches	1.6 inches.
Inside diameter	¾ inch	1 inch.
Inside length (cylinder)	2.6 inches	2.8 inches.
Length of stroke	0.9 inch	1.07 inches.
Diameter of piston	¾ inch	1 inch.
Length of piston proper	1.7 inches	1.73 inches.
Length of piston rod (for impact against tool)	0.9 inch	1.5 inches.
Weight of piston (with rod)	3 ounces	6 ounces.

By means of the tuning-fork mechanism shown in figure 5 and diagrammatically in figure 6, the rate of vibration of various tools was measured.[1] The apparatus consisted simply of a copper platen attached by an adjustable clamp to the tool whose vibration was to be measured. The platen was smoked after being fixed to the tool, by moving it over a bit of ignited camphor. While the tool was being used on a piece of stone, a tuning fork with tracing point attached, was drawn rapidly across the platen. If the tool were not vibrating, the resulting curve would show merely the smooth vibrations of the tuning fork. If the tool vibrated at the same time, the compound curve would show a certain number of the smooth tuning fork vibrations and also the sharp strokes of the tool, giving peaks different in shape, height, and number from those caused by the tuning fork. The ratio of the number of the former peaks to the number of the latter in a given distance on the tracing gives the rate of vibration of the tool when that of the fork is known.

Various hammers, even of the same size and type, and with the same registered air pressure, were found to give rather widely varying rates of vibration, dependent apparently on the pressure exerted by the stonecutter against the stone and on the lubrication and amount of wear of the hammer. It was soon found that with a range of tuning forks the rate of vibration could be gauged fairly accurately

[1] The writer is indebted to Prof. A. L. Foley of the Department of Physics, Indiana University, for suggesting and perfecting the details of this apparatus. It is simple and appeared to be the most accurate of several which were considered.

by comparing the pitch of the main note given by the vibrating tool, with that of the tuning fork corresponding most closely to it. However, especially when forks with low amplitude of vibration were used, it was found that accessory vibrations of the tool, sometimes two or three times as frequent as the main vibrations, were recorded

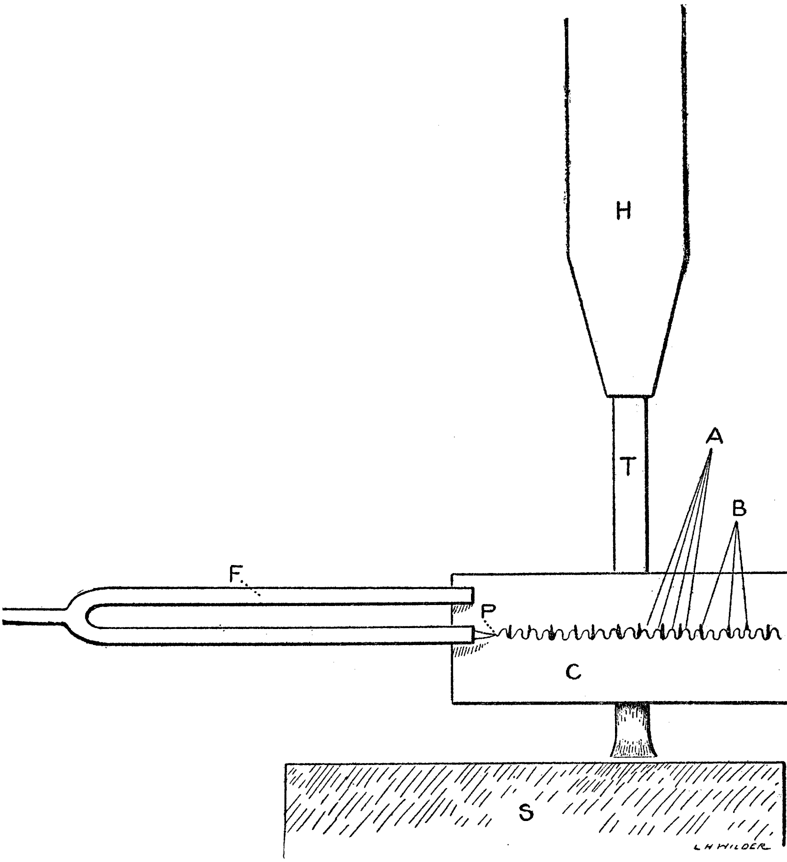

FIG. 6.—Diagram of the method of measuring rapidity of vibration. H, air hammer; T, vibrating tool; F, tuning fork of known vibration frequency (n per second); C, smoked copper platen, firmly fixed to the vibrating tool; P, point attached to tuning fork for tracing vibration curve as the fork is drawn rapidly across the face of the platen; S, stone; A, smooth peaks of the curve, caused by the vibrations of the tuning fork; B, sharp peaks of the curve, caused by the vibrations of the tool. If there are a smooth peaks and b sharp peaks in a given length of the curve traced by the tuning fork, the tool vibrates $\frac{b}{a}$ times as fast as the tuning fork, giving a rate of $\frac{bn}{a}$ vibrations per second.

on the platen; these were presumably caused by the elasticity of the stone and steel, the tool reverberating between the stone and hammer after each stroke of the piston. With 85 pounds pressure, the 1-inch hammer gave a main vibration rate varying between 88 and 136 per second (5,000 to 8,000 per minute), and the three-fourths inch up to 167 per second (10,000 per minute). This is

much more rapid than the figures usually given, and still does not take account of the more rapid accessory vibrations.

The method of using the air hammer may be seen in figures 2 and 3. The hammer itself is held by a right-handed person in the right hand, between the thumb and forefingers in much the same way as a pencil or pen is held. Some of the stonecutters regulate the power of the stroke by holding the thumb or forefinger over the exhaust. This may create a callus or a small area of insensibility at times, but does not appear to be productive of any serious results. The tool is held in the left hand, the most powerful part of the grasp and that controlling the direction of the cutting edge being exerted by the ulnar part of the hand. The direction of the hammer and tool is diagonal to the surface of the stone, and the rotation of the chisel about its own axis as well as the depth of the cut must be controlled very accurately. Since the tool is slender and rotates freely in the hammer, this necessitates a very firm and constant grip with the left hand. These points are important, as will be shown later. Some of the air hammers, presumably those which were considerably worn, were observed to discharge air along the piston rod and tool, against the fingers of the hand which held the tool. This was not observed to cause serious discomfort, but may have interfered with the power of the stroke.

The work is fairly continuous. Frequent changes of position and interruptions to blow away dust, make measurements, and change tools occur, but the hammer is in the hand and operating for the greater part of the time. Competition in speed, in part stimulated by the foremen or subcontractors, in part natural to the stonecutters, is probably keener than in smaller shops under the old conditions of stonecutting; in Bedford, stonecutting has been transformed to a factory occupation.

Heat was furnished in one of three ways: First, by hot air conduits opening in the vicinity of the stonecutters, as shown in Figure 2; second, by steam pipes around the side of the building; third, by coke-burning salamanders. Of these the latter appeared to be the most efficient, and the mills were so open that danger from carbon monoxide poisoning was minimal. However, since cold appears to be a factor in the production of discomfort from the use of the tool, it would be advisable to install radiators or other devices for heating the tools and the hands on cold mornings, in closer proximity to the cutters than the hot-air conduits and the steam pipes. The temperature in the mills is much less severe than in the open sheds where stonecutting has customarily been done. In one mill when the outside temperature was 16° F. at 7.30 a. m., the temperature where the stonecutting took place was observed to be 38° F. at the same time. In another mill the inside temperature was 40° F. when the outside

temperature was 22° F.; in a third the inside temperature was 40° F. when the outside temperature was 26° F. In two metal plants where pneumatic tools were being used the temperatures were 45° F. and 62° F. when the outside temperatures were 19° F. and 21° F., respectively.

As regards lighting, conditions were satisfactory. The stonecutting is usually done at one side of the mill and therefore near windows.

2. Other Uses of Vibrating Pneumatic Tools.

The use of pneumatic tools was also observed and tried in drilling holes in limestone, in cutting granite and other hard stone, in riveting metal plates, in calking boilers, in chipping castings, in cutting metal preparatory to calking, and in cutting grooves on sheet metal.

In the mills and at the quarries, reciprocating pneumatic drills, called "plug drills," are used for drilling holes in the blocks of stone for hoisting and for breaking. These drills are much larger than the air hammers used in stonecutting, especially in length of stroke, and the rate of vibration is much slower. The hammer has a pistol or shovel grip, and the tool, or drill proper, is guided by the left hand only at the first application to the stone; when the hole has been started, both hands grasp the hammer. Moreover, the drill is of larger diameter than the tool in stonecutting, and the grasp does not need to be as rigid or to direct the point as accurately as in the latter work.

In granite and monument cutting, the air hammer and tools are like those used in the Indiana limestone belt. Part of the granite cutting, however, is a pulverization of the stone, with the hammer and tool held perpendicular to the surface. It is apparent that when the work is of this character the grip on the tool is not of necessity as firm as when diagonal cutting is done. The main vibratory rates and the accessory vibrations were found to be similar to those in the limestone mills. The tendency toward vasomotor spasticity in the left hand (to be described later) was observed in the granite cutters, but not as uniformly nor to as marked a degree as in the limestone cutters.

In hot riveting outdoors and in hot and cold riveting in shops and mills the largest hand air hammers are used, those with pistons $1\frac{1}{16}$-inches diameter and a 9-inch stroke being a common size. These give about 20 vibrations per second. Here both hands are on the hammer, which usually has a pistol grip; the cap or "set" which hits the rivet is attached to the hammer by a spring clutch and does not need to be held. Riveting by sledge hammer was also observed; a rivet is headed as quickly by this method as by the use of the pneumatic hammer, but the strain on the men is much more severe. No cases of vasomotor spasticity were discovered among pneumatic rivet men.

In calking metal seams, a smaller hammer is used than in riveting, and the calking tool is held in the hand, but a firm, rigid grasp is not necessary, as the action of the hammer is perpendicular to the surface and the tool guides itself to a large extent.

The chipping preparatory to this calking, on the contrary, is inclined work. A triangular ribbon of steel is cut from the upper plate in order to make a bevel for calking. Grooving a sheet of metal is a somewhat similar process. Not so much attention, however, is directed in these cases to make the finished job smooth in appearance as in stonecutting, and the grasp on the tool is consequently not so rigid or continuous. The vibration rate is about 50 per second.

Chipping rough projections from castings is like the processes just described, but frequently larger hammers are used. Some of the tools used for this purpose have a hexagonal butt which fits into a six-sided opening in the end of the hammer snugly enough to prevent turning, but allowing free up and down motion. With the pistol grip, which is almost universal in pneumatic hammers for metal work, this enables the operator to guide the tool well with the hammer hand, and to relax the grasp on the tool to some extent. None of the metal workers who used air hammers admitted the blanching of the hands which was found so frequently in limestone cutters.

In a search in Pittsburgh through hospital records, interrogation of physicians with large practices among the metal workers, and an examination of several gangs of men chipping shell cases and steel wheels, the only case of pathological blanching of the hands which was found was in a man who had acquired it while cutting granite. This man did not complain of the hand condition but quit stonecutting for more sedentary metal work because of a subdeltoid bursitis with sudden onset 16 years after he began to use the air hammer. The chippers, who had been working with the air hammer for 3 to 12 years, had no complaint; it was noted, however, that these were men of stocky build and that they diminished the amplitude of the vibration by bracing their bodies against the hammers. The hammer used had a piston diameter of $1\frac{1}{16}$ inches and a 3-inch stroke. At 100 pounds pressure about 32 strokes per second or 1,800 per minute were delivered. The very fine secondary vibrations, or "overtones" were much more rapid than in the stone tools, being 20 to 40 times as frequent as the main strokes; but it is probable that these secondary vibrations in either case, on account of their very low amplitude and force, are practically negligible. In chipping the tool does not need to be guided with great accuracy and some of the more skillful chippers do not hold the tool at all except in starting and finishing.

It is thus seen that in these other uses of the pneumatic hammer (except granite cutting, which is somewhat similar to limestone cutting) the rate of vibration is slower and the grasp on the tool less constrained and constant than in the occupation under consideration. We should therefore expect that if the vibration itself had any deleterious effect, this would be at a maximum in the case of the stonecutters.

3. The Pulmonary Hazard.

Though this investigation was primarily directed to ascertain the possible effects of the air hammer in producing nervous disorders, it was deemed worth while to secure some data on the pulmonary hazard, since dust is commonly supposed to be the one great danger in the stonecutting trade. The infiltration of the lung with dust particles is known as pneumokoniosis, in the case of stone dust, as chalicosis; the result is a fibroid phthisis giving rise to dyspnœa, less often to cough and expectoration, at times fatal in itself, but more commonly found at necropsy when the direct cause of death has been tuberculosis. We may therefore consider the dust as predisposing to pulmonary infection with tubercle bacilli—less often with pneumococci or other organisms—and we may expect to find chalicosis expressed in the death records as pulmonary tuberculosis.

All prior statistics based on this assumption class stonecutting as a somewhat hazardous occupation. In this country the census of 1900 [1] recorded 33 per cent of the deaths among marble and stonecutters as due to pulmonary tuberculosis, while for all occupations (males) the percentage was only 14.5. In 1909 [2] 28.6 per cent of marble and stonecutters, 14.8 per cent of all occupied males, and 21 per cent of all occupied females who died, died of pulmonary tuberculosis. Hoffman [3] has reported the experience of the Prudential Life Insurance Co., 1907–1910: 47.8 per cent of the deaths among stone workers 25 to 44 years of age and 32.3 per cent of those 45 to 64 years of age were due to tuberculosis; among all occupied males the percentages for the two age groups were 38.5 and 14.1, respectively.

Through the courtesy of the officers of the Journeymen Stone Cutters' Association of North America, part of the death records of this organization were summarized. Of 343 deaths among stonecutters with assigned cause, 56 per cent were credited to pulmonary tuberculosis, stonecutter's consumption, and fibroid phthisis. On every count, then, stonecutters have suffered severely from chronic pulmonary disease, presumably caused by the stone dust.

---

[1] Twelfth Census of the United States. Vital Statistics, Part 1, Table 8, p. 154. Washington: United States Census Office, 1902.

[2] Mortality Statistics, 1909. Tenth Annual Report. Table VIII, pp. 402, 388. Washington: Government Printing Office, 1912.

[3] Hoffman, F. E. Exhibits of the Prudential Insurance Co. of America. International Congress on Hygiene and Demography. Pp. 29, 24. Washington, 1912.

I am indebted to Dr. Harvey Voyles, registrar of Bedford, for access to the original mortality records of that city, which are in good shape for the past 10 years, except for some uncertainty (as is common in death records) as to stillbirths; on this latter account only persons over 1 year of age were considered. To secure a basis for comparison, the United States Mortality Records were similarly summarized for 1910–1915, the middle six years of the past decade, since the records for 1916 and 1917 are not available. For the registration area, 11.3 per cent of all deaths in this age-group (11.9 per cent in males, 10.5 per cent in females) were due to tuberculosis of the lungs, for Indiana 11.5 per cent. For Lawrence County, Ind., 12.6 per cent of deaths at all ages were due to pulmonary tuberculosis; for the registration area 9.4 per cent at all ages, and for Indiana either as a whole or disregarding cities of over 10,000 population in 1910, 9.9 per cent. The population of Bedford was 8,716 at the last census. The tuberculosis proportional rate in Lawrence County is thus seen to be above normal. But beside Bedford and the limestone mills, Lawrence County contains the town of Mitchell, near which are large cement factories. Many cement works are notoriously dusty, and both locally and generally have a reputation for high consumptive rates. The death rate per thousand from pulmonary tuberculosis in the registration area for the six-year period was 1.31, in Indiana 1.29, in rural Indiana including all of Lawrence County 1.24, in Lawrence County 1.60.

Among stonecutters in Bedford 15 per cent of the deaths during the 10 years were due to pulmonary tuberculosis. Among all the workers in the stone mills, including the planer men, 12 per cent of the deaths were assigned to this cause. No disproportionately high number of deaths was assigned to other respiratory or heart disease, under which titles might be found fatalities really due to chalicosis. Among all other males of the same age group (23 to 72 years) the proportional rate was 13 per cent; among all females 21 per cent; among all persons over 1 year of age the proportional rate (from tuberculosis of the lungs) was 13.3 per cent, corresponding to 11.3 per cent for the registration area.

Objections might be justly raised to absolute conclusions from these statistics alone in that for some items there were only a small number of deaths—only two deaths from phthisis were recorded for Belfast stonecutters during the 10 years; also that the age groups were very broad and that proportionate percentages instead of actual death rates were compared. In regard to the small size of the items, it is to be noted that the classes are not subject to the allowances made for samples, but that they represent the total number of deaths. The age distribution was not strikingly dissimilar in the different classes. The possibility of consumptive stonecutters

having left the trade or sought other climates is to be considered, but the higher percentage of tuberculosis in Bedford among females than among males would argue against the assumption; for if the affected stonecutters had left the trade, while still remaining in Bedford, we should expect a disproportionately high rate among the males of that age-group as compared with the sex which is not subject to the hazard.

It accordingly appears that while Bedford has a proportional death percentage from phthisis slightly above normal, it has been no higher for stoneworkers than for other classes of the population, including females.

This agrees with what could be learned from a canvass of the physicians of Bedford and from the stonecutters themselves. The only case of consumption in stonecutters about which information could be obtained in this way was in a man who developed the disease nursing his wife through a fatal tuberculosis. No X-ray chest plates were made, but in examining the men no symptom or sign which could be attributed to pneumokoniosis was found.

The mills were not as dusty as several granite monument shops which were visited, but the difference was not striking, except for the fact that in the monument shops the dust was in the air, while in the limestone mills the dust was almost entirely on surfaces. There are at least four conceivable explanations for the comparative immunity of the Bedford stonecutters: (1) The particles may be larger and heavier than in the cutting of other stones; as one looked down the stonecutting aisles of these mills the visible cloud of dust from each tool stopped far below the face of the worker. In general the exhaust from the pneumatic tool blows what dust is formed away from the breathing zone. In limestone cutting the action of the tool is chipping at an acute angle with the surface of the stone; as explained before, in granite cutting the action is frequently perpendicular to the surface and possibly more pulverizing. (2) The blocks of stone as they reach the cutter in the mills, though not visibly wet, retain some of the moisture from the sawing processes. This reduces the dustiness of the cutting. (3) It is possible that the particles from the oolitic limestone are rounder and smoother than those from other stones; an accurate microscopical comparison was not made. (4) By some theories, calcium salts have a beneficial action in tuberculosis, aiding in walling off chance lesions from further activity. In general, the cutting of limestone has been held to be less perilous than the cutting of sandstone or granite. In any case, stonecutters appear to suffer less in Bedford than elsewhere from the dust hazard.

Associated with the dust hazard is the hazard from flying chips, largely an ocular one. Only a small proportion of the men were observed to wear protecting goggles. But on account of the inclina-

tion of the hammer the direction of the chipping is away from the worker's eyes. The physicians and oculists in Bedford state that while eye injuries occur in the stone mills, the most numerous and severe are not among the workmen who handle the stone, but among the metal workers, machinists and tool sharpeners; stone particles rarely cause more than temporary injury.

4. The Nervous Hazard.

At the outset of the investigation it was observed that the stonecutters on cold mornings were likely to have the fingers and ulnar side of the left hand white, cold, and numb. The investigation was primarily directed toward ascertaining the seriousness of this condition and whether other nervous troubles might be attributable to the use of the air hammer. The general findings and conclusions in this regard are given in Prof. Edsall's report. The writer is deeply indebted to Dr. Edsall for advice and collaboration, and for making by far the greater part of the more thorough examinations.

Many have considered the action of pneumatic tools to be unduly fatiguing or to subject the nervous system to some mysterious injury, but no data have been available sufficient for drawing conclusions in the matter. Southard and Solomon [1] have reported a case of pain and numbness in the hand of a granite cutter, in whom they found a slight anesthesia demonstrable only by Martin's electrical sensory test. This cutter had used a pneumatic tool for 15 years; the Wassermann reaction was positive. In this investigation it was felt that changes in sensation perceptible to the examiner only by use of a faradic current and not by any of the ordinary tests or by functional ability, in the first place must be very slight, and in the second place, especially in the question of occupational neurosis, might be rather dubious.

The following form was used to record the histories obtained at the time of examination:

Name...................... Residence.................. Age..................
Years with air hammer.... Years with mallet.... Type hammer used....Stone....
Character of work (roughing, finishing, carving)............ Where..............
Finger complaint............ Location.......... When first noticed............
(Underline condition observed at examination.)
Other complaints:
Sleep....... Pain....... Numbness....... Cold......... Breath........
Exhaust control....................... Along tool............................
Opinion as to best form of hammer and character of work..........................
Date examined............ Hour.................. Location..................
Temperature outside.............. Temperature where examined.................

[1] Southard, E. E. and Solomon, H. C.: Occupation Neurosis, p. 288 in Kober & Hanson's Diseases of Occupation and Vocational Hygiene. Philadelphia: 1916.

Beside the 19 men examined by Dr. Edsall, three other cases were examined in detail because they were commonly reported to be among the most severe sufferers from the use of the air hammer. Two were said to have stopped stonecutting on this account, and had left the Bedford district. In none of the three was there evidence of any organic change of consequence which could be attributed to the hammer. On the right forefinger of one man there was an area of diminished temperature sense; this was the finger used in controlling the exhaust. Callouses interfered with pain and touch sensitiveness over part of the hands, and when the parts were cold all sensibility was obtunded, but not more in any of the three cases than was the case with the hands of the examiner.

Of those who had changed their employment supposedly on account of objections to the air hammer, one stated that he quit because he had a disagreement with the foreman about another matter, a second had sought easier and steadier work, but found that two years of indoor occupation made him more nervous than cutting stone with the air hammer. A third had been badly frightened by hearing a severe prognosis made as to the possible effects of the hammer; he was habitually nervous and apprehensive in using the pneumatic tool, but stated voluntarily that he would like to go back if it were improved so as to relieve the strain.

When the stone mills were visited soon after work started in the morning the greater part of the cutters and carvers showed a blanching of the ulnar part of the hand which held the tool, with numbness and lowered temperature. They stated that this occurred commonly, but not uniformly in any one subject, in winter and on cold, damp, spring mornings. It also occurred frequently when the hands were subjected to cold in any way. It could be brought out in many of the men weeks or months after they had stopped work by plunging the hands for a few moments into snow or cold water. The hands of the examiner, used as a control, would under those circumstances show the normal hyperemic reaction, as did also the right hands of the stonecutters usually. On the left hand, typically, the little finger and hyperthenar eminence, the ring finger, and the tip of the middle finger became white and nearly bloodless. This might involve other fingers and the palm of the hand. If the person were left-handed, the right hand would show the phenomenon.

Designating the digits as 1, 2, 3, 4, 5, in order from the thumb to the little finger, the following table indicates the distribution of this vasomotor hypertonicity as to the fingers affected:

TABLE 1.—*Distribution of blanching, by fingers.*

Case.	Tool hand.	Hammer hand.	Case.	Tool hand.	Hammer hand.
1	5		22	3,4,5	
2	5		23	3,4,5	
3	5		24	3,4,5	2
4	5		25	3,4,5	2
5	4,5		26	3,4,5	3
6	4,5		27	[1]2,3,4	
7	4,5		28	3,4,5	2,3
8	4,5		29	2,3,4,5	
9	4,5	2,3,4	30	2,3,4,5	
10	3,4,5		31	2,3,4,5	
11	3,4,5		32	2,3,4,5	
12	3,4,5		33	2,3,4,5	
13	3,4,5		34	2,3,4,5	
14	3,4,5		35	2,3,4,5	
15	3,4,5		36	2,3,4,5	
16	3,4,5		37	2,3,4,5	2
17	3,4,5		38	2,3,4,5	2
18	3,4,5		39	1,2,3,4,5	
19	3,4,5		40	1,2,3,4,5	
20	3,4,5		41	1,2,3,4,5	
21	3,4,5		42	1,2,3,4,5	1,2

[1] Little finger held under tool.

The greater number of the cutters showed the condition on the cold winter mornings during which the investigation was in progress: In one mill 5 out 6, in other mills 6 out of 7, 2 out of 4, 4 out of 7, 8 out of 11, and 5 out of 7. Usually, decided discomfort was experienced when the blood returned to the hand, but the work was not seriously interfered with. The apprentices, who did not use the air hammer, had colder left hands than right, but no clear history was obtained of the typical reaction in its marked form in men who used the mallet exclusively. A former boiler builder, now one of the sales force for a boiler factory, who never used a penumatic tool and had not heard of the above condition, described the same phenomenon as occurring in his left hand, following the use of hand tools in the boiler shop.

It is noteworthy that many of the older stonecutters state that they formerly had trouble of this sort, but do not have it at present. It is their belief that the younger workmen grip the tool too tightly. This spastic anemia, however, was sluggish in onset, taking months or more than a year for full development, and lasting equally long after the cause was removed; it occurred only in cold weather, and not continuously then. In spite of thorough search for the worst cases in and out of Bedford, no suggestion of any more severe changes than those described was obtained. There seemed no tendency for the anemia to go on to frostbite or necrosis. The use of gloves did not prevent the blanching.

Other nervous symptoms encountered bore more or less relation to the hand phenomenon. Sleep was disturbed in some cases by the hands and arms becoming numb very readily. Pains, particularly confined to the left side and extremities, were occasionally described, but did not appear to be more severe than would be encountered among groups of workmen of the same age and habits who did not use pneumatic tools. Those unaccustomed to the air hammer unquestionably suffered more severely from these functional nervous symptoms. A few minutes' early morning use of the hammer in cutting stone (longer than a momentary trial) gave the writer an unpleasant, cramped, slightly painful sensation in the 5th digit and ulnar side of the left hand, during the entire evening, with observable redness and swelling. The phenomenon was noticed before the use of the hammer was recalled. Recovery was complete over night. The factors concerned were evidently similar to the ordinary local fatigue and strain such as are commonly experienced from an unaccustomed employment. This is in agreement with the frequent statement of the stonecutters that their chief difficulty as regards nervousness and sleeplessness was when they began to use the tool, but that as they became used to cutting stone with the air hammer, these symptoms wore off. The development of the white fingers, however, is said to be more gradual, coming on in the winter after the pneumatic tool had been in use for some months.

It appears, then, that the continued use of the air hammer in cutting limestone leads to a disorder shown by a blanching of parts of the left hand, with cold and numbness; that this is not a serious disease, but in some cases decidedly disagreeable, and that measures should be instituted to prevent it. Of the three assigned causes, cold would appear to be merely the exciting cause. It would nevertheless be advisable to provide radiators or other means of heating the hands and tools of the stonecutters, giving a source of heat nearer to the working places than the present pipes and hot air conduits. Of the two other factors, the strain caused by the cramped position of the hand in grasping the narrow tool, and the vibration, the former would appear to be dominant but the vibration can not be eliminated as a cause since the phenomenon apparently does not occur in metal workers who use hammers with much lower vibratory rates, but who nevertheless guide the tool in somewhat the same way as do the stonecutters. The sensation imparted to the hand by the slower vibration is very different from that felt in the use of the air hammer in the stone works.

It has been suggested that changes along one or more of the four lines indicated below might be effective, but the problem is essentially a mechanical one, the object being to make the grasp of the left hand more comfortable and less straining, and also if possible to

relieve some of the vibration received by that hand. Until an effective method is in use, it is advised that there be periods of rest from the use of the hammer and narrow tool, to enable the muscles of the left hand to relax and change their position.

1. A tool of larger diameter would permit a more hygienic grasp. It is possible that due to the softness of the stone and the necessary accurateness of the work, the impact of a light tool is preferable to that of a heavy one, but it would appear that if pressed against the stone, it is the construction of the hammer and the air pressure which determine the impact rather than the weight of the tool. A heavy tool, moreover, would reduce the vibratory effect felt by the left hand.

2. The shank of the tool might be provided with a tight fitting cover of asbestos or other similar material. This would need to be very rigid in order to permit proper guiding of the tool.

3. Instead of a tight handle, as above, a handle permitting reciprocal but no rotary motion could be used.

4. The end of the hammer might be prolonged over the tool so that the left hand in guiding grasps this instead of the tool. The tool should then have a square or triangular shank or be provided with grooves to prevent any rotary motion, and should also have a spring catch such as the rivet set in a pneumatic riveter.

5. Conclusions.

1. The pulmonary hazard is much less in stonecutting in the Bedford plants than in stonecutting in general. This is unquestionably the great hazard in the trade and its relative absence in this center makes the occupation of a stonecutter here more healthful than elsewhere. The workmen are not exposed to severe weather, the workrooms are large and well ventilated. In some of the mills the sanitary conveniences and guards against the spread of intestinal infection are satisfactory, but in others improvements should be made.

2. There exists in the hands of stonecutters who use pneumatic hammers a hypertonicity of the blood vessels which shows itself as an exaggerated reaction to low temperatures.

This is not serious as to life or function, but is uncomfortable at times, and should be remedied. It is believed that this can be done without eliminating the tool, and suggestions are made to that end.